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Safety and Efficacy of Mini-Percutaneous Nephrolithotomy for the Treatment of Renal Stones in Pediatric Patients with Kyphoscoliosis: A Retrospective Analysis of Eight Cases

Mehmet Mazhar Utangac*, Onur Dede

Department of Urology, Faculty of Medicine, Dicle University, Diyarbakır, Turkey.

Correspondence to: Mehmet Mazhar Utangac, Department of Urology, Faculty of Medicine, Dicle University, Diyarbakır, Turkey. Email: drmazhar21@hotmail.com

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ABSTRACT

Purpose: The aim of this study was to evaluate the technical feasibility, safety, and efficacy of the mini-Percutaneous Nephrolithotomy (mini-PNL) procedure for the treatment of kidney stones in pediatric patients with complex anatomy such as kyphoscoliosis.

Materials and Methods: Eight patients with kyphoscoliosis who underwent mini-PNL (14 Fr) for kidney stones, with a mean age of 8.4 years (range: 6 to 14 years), were retrospectively included in our study. The mean stone size was 16.2 mm (range: 12 to 32 mm). All patients were evaluated preoperatively using computed tomography. The primary evaluation criteria were single-session Stone-Free Rate (SFR), operative time, fluoroscopy time, hemoglobin decrease, hospital stay, and perioperative complications (according to the Clavien-Dindo classification).

Results: All procedures were completed successfully. The mean operative time was 78.7 ± 18.5 minutes, and the mean fluoroscopy time was 92.5 ± 28.3 seconds. The mean hemoglobin decrease was 1.2 ± 0.5 g/dL. The SFR was 87.5% (7 of 8 patients). One patient had a clinically insignificant residual fragment smaller than 4 mm. No major complications were observed, but one patient (Clavien-Dindo Grade I) experienced transient fever. The mean hospital stay was 2.6 ± 0.7 days.

Conclusion: Mini-PNL represents as a safe and highly effective option for the minimally invasive treatment of kidney stones in pediatric patients with kyphoscoliosis. Surgical success in this challenging anatomical setting is closely related to meticulous preoperative evaluation and optimized patient positioning appropriate to the spinal deformity.

Keywords:

Mini percutaneous nephrolithotomy, Kyphoscoliosis, Pediatric urology, Kidney stones, Minimally invasive surgery.

Introduction

Pediatric kidney stone disease has been increasing worldwide in recent years; global and regional data show a significant increase in prevalence and number of cases, particularly related to changes in lifestyle and environmental factors [1]. Recent reviews and population-based analyses highlight that the incidence in children has accelerated over time and that the etiology is more multifactorial (metabolic [hypercalciuria, hypocitraturia, cystinuria], anatomic anomalies (kyphoscoliosis), infection, diet and environmental/socio-demographic factors) compared to adults [2]. In terms of gender differences, it has been reported that the frequency of stones increases significantly in female adolescents during the second decade and exceeds that of males [2]. Although the probability of recurrence varies, multicenter and cohort studies have shown that symptomatic recurrence can reach approximately 50% within three years [3] and is higher in the absence of preventive/metabolic evaluation; In a more recent pediatric cohort, recurrence was reported as 15%, and age >5 years, family history, stones ≥ 5 mm, and anatomic anomalies were identified as independent risk factors [4]. In addition, global projections to 2025 predict that the burden of pediatric urolithiasis will increase further in the coming years [5]. Taken together, these findings suggest that early metabolic/anatomical evaluation and site-risk profile-specific prevention strategies are critical for reducing recurrence in childhood stone disease.

Kyphoscoliosis is a complex three-dimensional spinal deformity characterized by both extreme kyphosis (humpback) in the sagittal plane and scoliosis (lateral curvature) in the coronal plane in the thoracic and lumbar regions. This structural abnormality not only severely limits the volume and flexibility of the thoracic cage, impairing respiratory function, but also has significant and multifaceted effects on the urinary system. This deformity leads to significant mechanical and physiological changes in the thoracoabdominal cavity. Its effects on the urinary system are multifaceted: rotation of the spinal column and deformity of the thoracic cage can create extrinsic pressure on the ureters, leading to urinary stasis [6]. Allowing urine to sit in the bladder or upper urinary tract for longer than necessary creates an ideal environment for bacterial colonization, significantly increasing the risk of recurrent urinary tract infections. Furthermore, bone resorption due to immobilization (immobilization hypercalciuria), neurogenic bladder dysfunction due to underlying neuromuscular diseases, chronic infections, and the use of certain medications predispose these patients to stone formation [7]. Among these factors, spinal deformities, particularly kyphoscoliosis, appear to be an important and compelling predisposing factor for Urinary Tract Stone Disease (UTSD) [8].

Planning kidney stone surgery in a pediatric patient with kyphoscoliosis presents one of the most complex scenarios in urological practice. This challenge stems from a multifactorial pathophysiology: spinal deformity and frequently associated spinal instrumentation preclude standard surgical positions

(e.g., prone position), severely limiting anatomic access; while thoracic cage restriction significantly complicates anesthetic management by reducing pulmonary reserve [9]. The primary challenge arises from the rotated retroperitoneal anatomy and significant alterations in the renal axis. This not only predisposes to urinary tract stasis and recurrent infections, increasing the risk of stone formation, but also makes planning and implementing a safe percutaneous surgical access extremely challenging [10]. Conventional Percutaneous Nephrolithotomy (PNL) carries a high risk of morbidity (e.g., thoracic or colonic injury) in these patients due to displacement of adjacent organs such as the thorax, pleura, and bowel. Therefore, minimally invasive alternatives are gaining increasing importance. Current guidelines and clinical studies recommend the use of modified techniques such as supine mini-PNL or flexible Ureterorenoscopy (f-URS) in this population [11]. The presence of spinal instrumentation and the deformity itself may preclude standard surgical positions (e.g., prone). The rotated renal anatomy significantly complicates the planning and implementation of percutaneous access routes [10]. PNL may carry a high risk of morbidity in these patients.

Fortunately, technological advances have enabled the development of smaller-diameter nephroscopes and instruments, giving rise to the concept of "mini-PNL." Mini-PNL utilizes narrower working tracts, typically ranging from 14F to 20F [7]. This technique offers the advantages of less renal parenchymal trauma, a lower risk of bleeding, and a faster recovery time compared to standard PNL [13]. These features make mini-PNL an ideal option for the pediatric kyphoscoliosis population [14], where preservation of renal function is crucial and anatomic variations are common.

While the literature lacks randomized controlled trials specific to this patient group, the available evidence comes from retrospective series and multicenter observational studies. The aim of this study is to retrospectively analyze the results obtained with the mini-PNL technique in eight pediatric kyphoscoliosis cases, to demonstrate the efficacy and safety profile of this technique in this challenging patient group, and to discuss the findings in light of current literature.

Materials and Methods

Patient Population and Ethical Approval

This retrospective cohort study was conducted after receiving approval from the Dicle University Ethics Committee (2025/308). The records of all patients under the age of 18 who were diagnosed with kyphoscoliosis and underwent mini-PNL for kidney stones between January 2022 and August 2025 were reviewed. A total of eight patients who met the study criteria were identified. Informed consent was obtained from the parents of all patients before surgery.

Pre-Operative Evaluation

All patients underwent a comprehensive pre-operative evaluation. This evaluation included:

- Detailed history (stone disease, etiology of spinal deformity, previous surgeries)
- Physical and neurological examination
- Complete blood count and biochemistry (creatinine, urea, electrolytes, calcium, phosphorus, uric acid)
- Complete urinalysis and urine culture
- Non-Contrast Computed Tomography (NCCT) to assess stone burden, location, and renal anatomy
- Posteroanterior and lateral spinal radiographs to assess the severity of spinal deformity
- Anesthesiology consultation (for risk of pulmonary restriction and difficult airway)

Surgical Technique (Mini-PNL)

All procedures were performed under general anesthesia by an experienced pediatric urology team.

Position: Patients were placed in the standard prone position or, if necessary, in a modified lateral decubitus position, taking into account their spinal deformities.

Cystoscopy and Retrograde Catheterization: Initially, cystoscopy was performed with the patient in the supine position, and retrograde pyelography was performed by inserting a ureteral catheter or a 4F ureteroscope into the ureter of the affected side. In patients for whom a ureteral catheter could not be placed, percutaneous access to the kidney was performed using ultrasound (Patient No. 5, Figure 1).

Position Change and Access The patient was then placed in the prone or modified lateral position. The collecting system was opacified with dye through the retrograde catheter.

Puncture: Under ultrasound and fluoroscopy guidance, an 18-gauge percutaneous needle was punctured into the most suitable calyceal (subcostal and papillary entry whenever possible) determined based on pre-operative computerized tomography (Figure 1: Ultrasound-guided entry into the calyceal system in our patient in row 5).

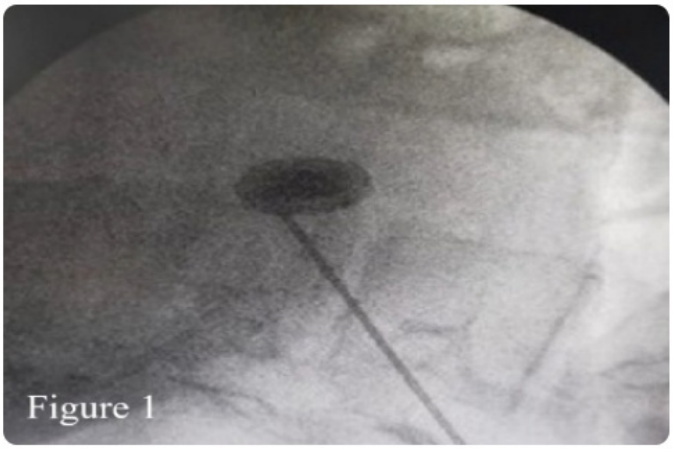

Figure 1: Ultrasound-guided entry into the calyceal system.

Tract Dilation: A guidewire was advanced through the needle into the collecting system, if possible, up to the ureter. A skin incision was then made, and the tract was dilated to a 14 Fr diameter using a single-stage dilator (Figure 2).

Nephroscopy and Lithotripsy: A mini-nephroscope (9.5 Fr) was advanced through the Amplatz sheath into the renal collecting system. Stones were fragmented using a holmium:YAG laser (200-365 µm fiber, 0.8-1.2 J, 8-15 Hz settings).

Stone Extraction: Small fragments were removed by aspiration with forceps or a basket catheter (Figure 3).

Final Procedures: A 10Fr nephrostomy tube was conclusion at the end of the procedure. The retrogradely inserted ureteral

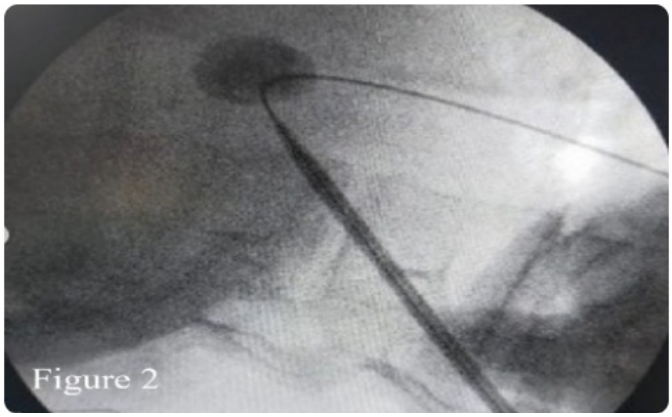

Figure 2: Tract was dilated to a 14 Fr diameter using a single-stage dilator.

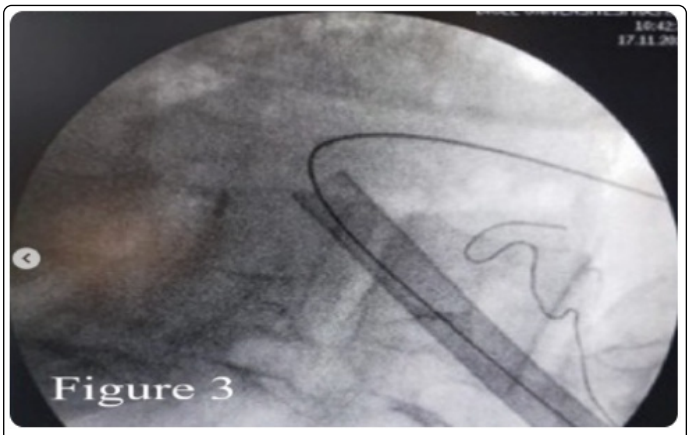

Figure 3: Fluoroscopy image after complete stone removal.

catheter was removed at the end of the procedure, and a DJ stent appropriate for the patient's size was inserted. The DJ stent was removed at 1 month post-operatively.

Post-Operative Follow-up

The nephrostomy tube was usually removed on the 1st or 2nd post-operative day. Patients were discharged after being evaluated for complications.

Single-Session Stone Free Rate (SFR): This was considered the primary outcome measure. Stone freedom was assessed with low-dose NCCT or ultrasonography performed at 1 month post-operatively. Asymptomatic residual fragments smaller than 4 mm were considered "Clinically Insignificant Residual Fragments" (CIRF) and were considered successful [9].

Complications: These were recorded according to the Clavien-Dindo classification during the 30-day post-operative period [10].

Other Parameters: Operative time (from the time positioning was initiated to the time the nephrostomy tube was placed), fluoroscopy time, the difference between pre-operative and 24-hour post-operative hemoglobin values, and total hospital stay were recorded.

Statistical Analysis

Data were analyzed using IBM SPSS Statistics 25.0 (IBM Corp., Armonk, NY, USA) software. Descriptive statistics were presented as mean ± standard deviation and range (minimum-maximum) for continuous variables and as number (n) and percentage (%) for categorical variables.

Results

The demographic, clinical, and surgical characteristics of the 8 patients (5 males, 3 females) included in the study are summarized in Table 1. All mini-PNL procedures (100%) were technically successful, and no patient required conversion to standard PNL or open surgery. The mean operative time was 78.7 ± 18.5 minutes (range: 55 to 120 minutes), and the mean fluoroscopy time was 92.5 ± 28.3 seconds (range: 45 to 150 seconds). All patients received age-appropriate DJ stents.

Single-session SFR was 87.5% (7 of 8 patients). Patient 8 (32-mm staghorn stone) had a 3-mm residual CIRF and was placed on metabolic follow-up. The mean hemoglobin decrease was 1.2 ± 0.5 g/dL (range: 0.6 to 2.1 g/dL). No patient required a blood transfusion.

Table 1. Demographic, Clinical and Surgical Characteristics of Patients (n=8).

Number	Age	Sex	Left/Right	Burden mm	Stone Location	Surgery Position	Operation Time (min)	Fluoroscopy time (sec)
1	6	M	Left	12	Lower calyx	Prone	65	70
2	7	F	Right	14	Pelvis	Modified Lateral	70	85
3	8	M	Right	18	Pelvis	Prone	80	90
4	8	F	Left	15	Upper calyx	Prone	75	60
5	9	M	Right	20	Pelvis	Modified Lateral	95	110
6	10	M	Left	22	Pelvis	Prone	100	135
7	12	F	Right	17	Pelvis	Prone	85	90
8	14	M	Left	32	Staghorn	Modified Lateral	120	150

When examining complications, one patient (Patient 8, 32 mm staghorn stone) developed a fever of 38.2°C (Clavien-Dindo Grade I) at 24 hours post-operatively. Despite no positive urine culture, empirical antibiotic therapy was initiated, and symptoms resolved within 24 hours. No major complications (Grade III and above), thoracic complications, septicemia, or organ injury were observed. The mean hospital stay was 2.6 ± 0.7 days (range: 2 to 4 days). One patient's DJ stent spontaneously dislodged from the urethra. The other patients' DJ stents were removed under sedoanalgesia.

Discussion

In patients with spinal deformities, abnormal renal and urinary system anatomy, recurrent urinary tract infections, decreased functional excretion due to physical immobility, and accompanying urine stasis, all combined, significantly increase the risk of developing urolithiasis. This pathophysiological process facilitates both the development and recurrence of

stone disease by predisposing to both infectious (struvite) stone formation and crystal deposition triggered by metabolic imbalances (hypercalciuria, hypocitraturia, etc.) [17].

A wide variety of treatment modalities are available for the management of nephrolithiasis, including open surgery, extracorporeal shock wave lithotripsy, PNL, Retrograde Intrarenal Surgery (RIRS), and laparoscopic surgery [12]. These options, particularly within PNL, have become the gold standard for the management of kidney stones ≥ 2 cm in size over the past two decades [13]. With increasing surgical experience and technological advancements, the indications for PNL have expanded significantly, becoming an effective standalone treatment option for patients with altered renal anatomy, those with a single functional kidney, those who have previously undergone renal wave surgery, those with high stone burdens and complex stone shapes, and those with physical conditions such as morbid obesity or spinal deformities [18]. Pediatric kidney stone surgery requires a unique approach due to fundamental physiological and anatomical differences from adult practice. The smaller body volume, less blood volume, and immature homeostatic mechanisms of pediatric patients make intraoperative fluid management critical and their tolerance for complications such as blood loss lower [19]. Anatomically, the smaller urethral caliber, more miniature kidney dimensions, and closer organ proximity dictate the choice of surgical instruments (thinner nephroscopes and ureteroscopes) and technical precision [18]. Therefore, procedures such as PNL, routinely performed in adults, are performed with modified, less invasive techniques such as “mini-percutaneous” or “Ultramini-Percutaneous” (UMP) in the pediatric population [20].

Pediatric patients with kyphoscoliosis are at high risk for urinary tract stone disease, and their surgical management presents significant challenges. Therefore, PNL in children with kyphoscoliosis represents one of the most complex areas of pediatric stone surgery. The challenges encountered in this patient group include not only technical aspects but also anesthesia, perioperative monitoring, and complication management. Kyphoscoliosis is an independent risk factor for UTSD. A systematic review by Silva et al. reported that the prevalence of UTSD in children with spinal deformities is significantly higher than in the general pediatric population [8]. The mechanisms underlying this increased risk include urinary stasis, hypercalciuria due to immobility, chronic infection, and neurogenic bladder dysfunction [6,7]. Therefore, these patients require a multidisciplinary approach not only for stone treatment but also for comprehensive metabolic evaluation and medical therapy.

One of the most significant technical challenges in surgical treatment of pediatric kyphoscoliosis is appropriate patient positioning during surgery and ensuring safe percutaneous renal access. In addition to the significant spinal deformity, the presence of spinal instrumentation (rods, screws, and fusion materials) in some patients limits the applicability of the traditional prone position and complicates anesthetic management by disrupting the thoracic-pressure relationship. Therefore, considering access safety and respiratory mechanics, the prone position is considered high-risk in a significant portion of children with kyphoscoliosis. In this context, as reported by Lorenzis et al., lateral or modified lateral decubitus positions are reliable alternatives that allow for the optimization of percutaneous access angles and increase ventilatory stability in patients with spinal deformities [16]. Similarly, in our series, a modified lateral position was chosen in three of eight patients (37.5%) due to the degree of deformity. Even in these patients, mini-PNL procedures were successfully completed by ensuring safe calyceal puncture with ultrasound and fluoroscopy guidance. These results demonstrate that position modifications can be implemented with high success and a low complication rate despite anatomic challenges.

The most significant advantage of mini-PNL in this particular patient group is that it causes more limited vascular and tissue trauma to the renal parenchyma compared to standard PNL. The smaller diameter of the working channel reduces mechanical stress on the renal parenchyma and the likelihood of injury to blood vessels at the access site, resulting in a significant reduction in both blood loss and transfusion requirements. Indeed, recent systematic reviews and meta-analyses report that blood transfusion rates in pediatric mini-PNL are less than 1%, a value that is statistically significantly lower than those reported in standard PNL series [12,13]. Our series also confirmed the significant hemodynamic safety profile of mini-PNL. The mean hemoglobin decrease of only 1.2 g/dL and the fact that no patient required blood transfusion support this technique as an approach that preserves renal function and minimizes the risk of complications, even in anatomically challenging cases of kyphoscoliosis.

Elmansy et al. reported that the SFR of mini-PNL was significantly higher than that of Retrograde Intra Renal Surgery (RIRS) for lower calyceal stones measuring 1-2 cm [21]. Similarly, Jia et al. found that mini-PNL was associated with a higher SFR and a lower need for additional procedures compared to RIRS in patients with stones measuring 1-2 cm [22]. In terms of efficacy, the SFR of 87.5% is consistent with the pediatric mini-PNL literature. Mini-PNL may offer higher clearance rates than RIRS, particularly for lower calyceal stones and stones >15 mm in size. Achieving SFR in a single session for even a 32-mm staghorn stone in our series demonstrates the effectiveness of the technique even with large stone burdens. This study demonstrated that mini-PNL can be applied to the treatment of kidney stones in pediatric patients with kyphoscoliosis with high technical success (100%), high efficacy (87.5% SFR), and an acceptable safety profile. These findings are consistent with recent literature emphasizing the superiority of minimally invasive techniques in patients with complex anatomy.

Our complication profile reflects the low morbidity advantage of mini-PNL. Apart from a Clavien-Dindo Grade I complication (fever), no major complications were observed. This supports the view that smaller tract diameters result in less pain and faster recovery, as reported by Feng et al. [23]. In a study comparing mini-PNL and standard PNL, the mean hospital stay was 2.8 days in the mini-PNL group, compared to 3.5 days in the standard PNL group [24]. The data from our study also support this finding, with the mean hospital stay of 2.6 days recorded in our series representing a significant reduction compared to pediatric standard PNL series. This suggests that mini-PNL may allow patients to return to their daily activities more quickly.

Several methodological limitations of this study should be considered. First, the retrospective design of the study carries the risk of selection bias, which can inevitably arise in patient selection and data recording. Furthermore, the relatively limited number of patients and the fact that the analyses were limited to single-center experience reduce the generalizability of the results to a certain extent. Another limitation is that the surgical treatment selection process did not include randomization, and therefore, the effectiveness of mini-PNL could not be directly compared with other endourological methods such as RIRS or standard PCNL. However, the study's focus on pediatric patients with kyphoscoliosis, a rare and challenging comorbidity requiring surgical management, stands out as a significant strength. This patient group is represented in the literature with very limited data due to anatomic challenges and perioperative risks. Therefore, the findings contribute significantly to the existing literature by demonstrating the feasibility, safety, and therapeutic value of mini-PNL despite these specific challenges.

Conclusion

The results of our study demonstrate that mini-PNL is a safe, feasible, and highly effective option for the treatment of kidney stones ranging in size from 12 to 32 mm in this patient group. The low bleeding risk, high stone-free rate, low complication profile, and short hospital stay make mini-PNL a superior alternative to standard PNL for children with kyphoscoliosis. Success depends on meticulous pre-operative imaging, appropriate patient positioning for the spinal deformity, and performance by an experienced surgical team. In the long term, comprehensive post-operative metabolic evaluation and medical management are essential to prevent stone recurrence in these patients.

Conflict of interest

None.

Funding

None.

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